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J. Hampden

A gift from the author in
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Jamison



On the OLDER METAMORPHIC ROCKS and GRANITE of BANFFSHIRE.

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INTRODUCTORY.

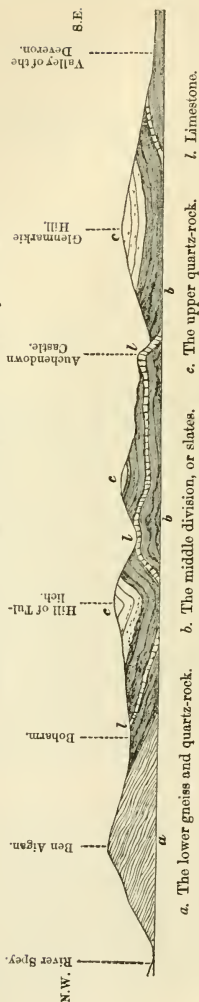
THE information we have regarding the geology of Banffshire is chiefly to be found in Dr. MacCulloch's map of Scotland, a memoir by R. J. Cunningham in the Transactions of the Highland Society, 2nd ser. vol. viii. p. 447, and a paper by Professor Harkness in the Quart. Journ. of the Geol. Soc. for 1862, vol. xviii. p. 331.

Mr. Cunningham's memoir deals with the structure of the whole county, and is accompanied by a map and some sections, while the paper of Professor Harkness describes the section of the rocks exposed along the coast. I have carefully examined the whole of the section described by Professor Harkness, and also the coast eastward as far as Fraserburgh; but being unable to satisfy myself as to the true succession of all the various beds which are there exposed, I betook myself to the interior of the country; and from an examination of the district lying between the Spey and the Deveron, I was enabled to arrive at clearer views regarding the relation of the various strata to one another, and have constructed a section (fig. 1) extending from near the village of Rothes, on the river Spey, in a south-easterly direction by Mortlach, and the Old Castle of Auchendown, for a distance of about twelve miles, which shows the succession of the beds very distinctly.

THE THREE DIVISIONS OF THE STRATA.

At the bottom we have a great thickness of arenaceous beds, which rise up at the western end of the section, beside the river Spey, and are more or less altered by metamorphic action into quartz-rock, gneiss, and mica-schist (fig. 1, *a*). The base of this series is not exposed, and it seems to extend across the Spey for some distance into Morayshire. In tracing the section eastward, we find these lowermost beds disappearing underneath a series of fine-grained argillaceous beds or clay slate (fig. 1, *b*), varying in colour from green to a very dark, almost

Fig. 1.—Section from the Spey to the Deveron, a distance of 12 miles.



blackish hue. In the midst of this mass of clay-slate there is a bed of limestone (fig. 1*l*); and both the limestone and the slate beside it often contain a large proportion of magnesia, and the varying metamorphism of these beds has in some localities given rise to masses of serpentine and talcose slate. This slaty series is covered by a second or upper group of arenaceous strata (fig. 1*c*), often assuming the character of quartz-rock of a very pure white colour, forming the top of many of the hills of this district. Although in many places this upper quartz-rock is much worn away, yet in some of the mountains in the higher parts of the county it attains a great thickness, and forms the uppermost bed of the old metamorphic rocks exposed in this region.

We see therefore that the arrangement and succession of the metamorphic strata here are very similar to what we find in Bute and Argyllshire (see *Quart. Journ. of Geol. Soc.* 1860, vol. xvii. p. 133), namely a mass of clay-slate enclosed like a sandwich between two great masses of arenaceous beds. The rocks of Banffshire, in fact, seem to belong to the same formation as those of Bute. That is to say, they form the north-eastern extension of those beds which range through the central Highlands of Scotland, from the Moray Firth to the Firth of Clyde. In mineral quality and state of metamorphism the resemblance is very close.

1. *The Lower Division, or Gneiss and Quartz-rock.*—The passage from the lower quartz-rock upwards into the slates may be clearly seen along the course of a small stream, locally known as the Burn of Mulben, on the east side of the Spey, which is traversed by the line of railway from Keith to Elgin. Near the mouth of the stream, where it falls into the Spey, the mineral quality of the rock is, when freshly broken, white and

quartzose, almost a pure quartz-rock, with ferruginous stains along the joints and planes of division. In Mac Culloch's map it is by some mistake coloured as part of the Old Red Sandstone, its arenaceous character having probably in some measure led to the error. As we proceed up the course of the stream the rock is seen to lie in gentle undulations dipping south-east at a low angle, the quality still much the same, but rather more micaceous—being a fine-grained micaceous quartz-rock, or quartzose mica-slate. Near its junction with the slate the rock becomes more micaceous—a ferruginous-stained micaceous grit, alternating with seams of mica-slate, often thin-bedded and well laminated lying in regular order and dipping south-east, at an angle of 30° or 35° . The colour now becomes greener and the lamination more distinct; and the passage upwards into the base of the overlying mass of slate is thus accomplished, there being thin seams of grit interbedded with the slate where it commences. The slate is here of a dull greenish colour, and is well exposed along the railway on to Mulben station, dipping south-east at from 30° to 40° . The mineral character of the group of rocks lying beneath the slate series may also be well studied along the western flank of Ben Aigan, where there are some deep gullies cutting far into the hill. The whole of this side of the mountain from top to bottom consists of these rocks, indicating a thickness of about 1200 or 1400 feet; and as they seem to extend across the Spey for some distance westward, the depth is probably very great. In such a mass of sedimentary strata there must of course be a considerable variety in the quality; and although the general character is quartzose, yet seams and beds of a softer and more slaty nature may here and there be met with. At one place I found the strata so rotten that considerable masses were reduced to the consistency of mud. The crushing, squeezing, and twisting to which the beds have been exposed have probably had something to do with this; and the occurrence of such rotten beds here and there in a mountain must greatly facilitate the operation of those forces which carve out valleys and have removed such immense quantities of rock from the surface in many places. The rapidity with which the waste occasionally goes on may be seen in a deep gully or trench in the west flank of Ben Aigan, which seems to have been excavated by the action of a petty stream of water, so insignificant that at some seasons of the year it is almost quite dry.

Similar masses of rotten rock, approaching the consistency of soft sandy mud, occur near the top of the Glenmarkie ridge to the east of Auchendown Castle, in the upper quartz, although part of the strata in the immediate neighbourhood is a hard-grained white quartz-rock, or metamorphic grit. It is interesting to examine this mouldering bank of rusty brown sand and mud, containing some seams of disintegrated slate, where we see the rock reduced to something like what we may suppose to have been the original condition of the bed when it lay at the bottom of the ancient sea.

In some places the lower quartz-rock is much impregnated with oxide of iron; and at Arndilly, on the west base of Ben Aigan, an at-

tempt was made to work a small vein of ironstone which occurs there. On the top of the hill the rock is of purer quality; and along the eastern slope it is covered by the clay-slate, which, however, seems to have its stratification more disturbed than at Mulben, and the junction is not so well exposed.

If the quartzose gneiss on the west side of the Spey comes out beneath the basement beds of Ben Aigan, as seems probable from the disposition of the strata, it would show that the thickness of the group of rocks lying beneath the slate is very considerable. The quartz-rock of Cullen lies on the line of strike of the Ben Aigan quartz, and is probably the northern extension of the same strata.

2. *The Middle Division, or Slates.*—With regard to the slate, the lower portion, as I have already mentioned, is well exposed to view along the line of railway at Mulben, and on the coast between Gamrie Head and Macduff there is a fine section. The limestone is exposed in a great many places along the river Dullan at Mortlach, the Loch of Drummuir, Auchendown Castle, &c. Its thickness varies a good deal in different places; and in the coast-section between Gamrie and Macduff no limestone occurs, so that it would seem occasionally to thin out altogether.

The thickness of the slate lying between it and the upper quartz-rock I estimated as about 500 feet in some places; and probably there is as much beneath it, which would make a total of 1000 feet for the mass of slates. But the thickness of the slate itself seems to vary a good deal, and to increase towards the coast. It probably consists of the finer sediment accumulated in deep still water, and would be thickest in the troughs of the old sea-bottom. We should therefore expect to find it thickening in certain directions. So far as I can judge, the thickness of the slate in this region seems to increase towards the trough of the Moray Firth. The arenaceous beds, which we may suppose to have been deposited in water that was shallower or more traversed by currents, seem to thicken, or bear a greater proportion to the slates, as we go towards the interior of the country, as, for example, in the region of Braemar and Glentilt, where the quartz-rock is much developed and of great purity.

3. *The Upper Division, or Upper Quartz-rock.*—The meeting of the slate with the upper quartz-rock may be seen in some of the gullies that rut the side of the hill which forms the eastern bank of the river Dullan, in the neighbourhood of a place known as the Giant's Chair, a little way above the village of Mortlach. This Giant's Chair is an old pot-hole worn by the former action of the stream in the limestone which here forms the bed of the river. The top of the ridge which divides the Dullan from the Fiddich consists of the upper quartz, and so likewise does the top of that which separates the Fiddich from the Deveron. In the latter ridge, to the east of the old castle of Auchendown, the slate may be seen forming the base of the Glenmarkie Hill, and has been quarried for roofing purposes here and there along its western slope; but the top of the ridge is of quartz. The slate may also be seen passing underneath the upper quartz-rock, on the eastern bank of the river Fiddich, opposite Bal-

venio Castle, close by the edge of the stream. Here the slate troughs the quartz in a synclinal fold, which is much more abrupt at one side than it is at the other; for as we walk along the river from north-west to south-east, we find the slate disappearing under the quartz at an angle of from 20° to 25° , and emerging again to the south-eastward almost vertically. The quartz-rock is here much crushed and disintegrated, as if by the nip it had got in the sharp curve of the synclinal fold.

THE GRANITE—ITS ORIGIN.

The granite of this region, I am inclined to think, has resulted from the fusion and recrystallization of the arenaceous beds. It is evident that the granite has originated after the deposition of these old sedimentary strata, because they are everywhere penetrated by its veins and injected masses, as may be well seen in the district around Lower Craigellachie. The granite, however, does not derange the strike of the beds to the degree that such a mass of foreign material should have done had it been erupted in an igneous condition, or forced up in any other conceivable way. I would rather suppose that the heat from the interior of the earth gradually approached the base of these sedimentary beds and, by heating, caused them to expand and thereby become wrinkled into huge folds, as a necessary consequence of a great mass of swollen matter having to find room in the space occupied by the same matter when in a cold and contracted state. The portions most liable to be fused would be softened and dissolved *in situ*, and be injected with enormous force, in consequence of the pressure, into all the openings and crevices around them. Crystallization would then take place as the whole very slowly cooled. In some such way, I imagine, the granite of this region has been formed out of the lower arenaceous and silty beds, and the greenstone of the Portsoy district out of the more argillaceous strata. The heat, as well as the watery vapour under such immense pressure, would probably penetrate further into the arenaceous beds than into the closer-grained clays. These views are confirmed by finding the granite occupying the room of what should have been gneiss or quartz-rock and the greenstone replacing the argillaceous beds. The serpentine of this region, as I have before mentioned, seems to have resulted from the metamorphism of beds containing much magnesia. In some places around Lower Craigellachie and the southern base of Ben Aigan, the gneiss is plentifully streaked with granite, as if partial fusion had just begun. These portions are found along the circumference of the great mass of granite, and seem to me to represent the gradual passage of arenaceous or silty strata by way of gneiss into granite. And here I may mention that the gneiss and quartz-rock of this region, even where most siliceous, always contains a proportion of felspar. The softening and fusion, as it progressed, would advance more rapidly along certain lines where the mineral matter was of such a nature as to yield most readily to the influence of the forces acting upon it.

As examples that may be easily examined, I may cite a section on the Dufftown Railway, at the Popine meal- and saw-mill, near Lower Craigellachie, also the rock at Craigellachie Bridge, and along the side of the Fiddich from Craigellachie Station to near Kininvie Castle. The rock of the hill called Upper Craigellachie near Aviemore, is also of a similar nature, so that in many places I should be at a loss to say whether the granite or the gneiss prevails. Along the Fiddich, from Craigellachie Station to near Kininvie Castle, the rock exposed in the railway-cuttings is a hard quartz, so full of veins that one is occasionally in doubt whether to pronounce it a stratified rock or a granite. In many places, where the aggregation of the mineral particles is granitic (rather small-grained and reddish), traces of the undulating bedding may be observed; in short, the rock seems to me to consist of the beds of lower quartz-rock merging into granite—that is to say, incipient granite, a stratified rock far gone on its way to granite.

In some places, near Craigellachie, there is a good deal of greenish matter in the rock, as if it had consisted of alternations of talcose schist or grit and quartz-rock, such as occur near the base of the slate on the Mulben stream, and also near the Giant's Chair, where the upper beds of slate meet the overlying quartz-rock. I observed that the small granite veins occasionally form alternating laminæ in the rock, and reddish streaks parallel to the bedding, the greenish matter segregating into irregular branching plates.

The hill called Little Conval, near Dufftown, is of granite, which at its south-eastern base I found to be large-grained and composed of red felspar and whitish quartz, with little or no mica; but higher up the rock becomes finer-grained, and at the top consists of a small-grained mixture of red felspar and quartz, much resembling some varieties of quartzose gneiss, such as that at Red Hythe Point, as if the metamorphism decreased in intensity as it passed upwards. The felspar, however, is redder than is usual in gneiss, and seems to bear a larger proportion to the quartz. There are the remains of an old stone rampart or enclosure round the crest of this hill.

THEORY OF THE DERIVATION OF THE SEDIMENTARY STRATA AND OF THEIR PRESENT STRIKE.

The general texture of the materials of which the gneiss, quartz-rock, and clay-slate are composed is fine-grained, and I observed no beds of conglomerate or large pebbles. The nearest approach to these which I saw was in the coast-section between Gamrie Head and Melrose, near a place called the Grey Mare's Point, where the anticlinal fold occurs that is shown in Prof. Harkness's section. Here I observed a seam composed of water-worn pebbles of white quartz, some of which were two inches in length. This is near the base of the slate, and is the nearest approach to a conglomerate that I have observed. But in general there is nothing larger-grained than what, in its original condition, would have been a coarse sand. It is a curious circumstance that such a thick mass of sediment

should have been accumulated showing so little variety in character, and without the occurrence of any large boulders or beds of conglomerate. Perhaps it may be explained by supposing it to have been accumulated in the depths of the sea, off the mouth of a great river like the Amazon, which may have been continually pouring in sediment, but with a current not sufficient to carry large pebbles. The slate, or fine argillaceous sediment, between the two great masses of arenaceous strata may be accounted for by a subsidence of the area of deposit into deeper and stiller water, where little except the finer sediment would be floated.

The Red (Cambrian) Sandstone and Conglomerate of the North-west Highlands, which stretches for a hundred miles from S.W. to N.E., with a comparatively narrow breadth in the opposite direction, looks as if it had been accumulated along a shore-line which was probably the coast of an ancient continent of the Laurentian gneiss. This Cambrian Sandstone is overlapped on its eastern border by the Lower Silurian schists and quartz-rocks of the Highlands, which we may therefore suppose to have been accumulated at a somewhat later period, but which, in all likelihood, consist of the sediment poured into the sea by the rivers draining the same Laurentian region to the north-west. After a great thickness of sediment had been accumulated, a glow of heat from beneath seems to have approached it, and by the expansion thereby occasioned wrinkled the mass into huge folds running from S.W. to N.E. The reason why the wrinkles run in that direction, I imagine, must be that expansion in the transverse direction was more difficult, owing perhaps to the opposing mass of the Cambrian and Laurentian land preventing extension towards the north-west side.

DISCUSSION.

Prof. RAMSAY observed that the general section wonderfully corresponded with that given many years ago by Sir Roderick Murchison of the Silurian and Laurentian rocks at Cape Wrath, and it seemed to him that the large views originally propounded by Sir Roderick were confirmed by the author. He was glad that the metamorphic origin of granite was supported by Mr. Jamieson, as he had held that view for many years; and he was pleased to find that opinions which had formerly met with so many opponents were constantly gaining acceptance. The fusion of these sedimentary rocks by metamorphic action was not identical with the fusion of lava; but their fluidity might be the same; and if that were the case, there could be no difficulty in accepting the possibility of the injection of such fused rocks into crevices and fissures. The crumpling of the beds, however, was due to more extensive causes than those contemplated by the author. The proportion of igneous rock injected into contorted rocks, like those of North Wales, was comparatively small, and the crumpling could hardly be due to mere local causes.

Prof. ANSTED referred to what he had observed in the north-west part of Corsica, where about 40 feet of granite was distinctly inter-

stratified between perfectly unmetamorphosed beds of sandstone and limestone, without any alteration at the points of contact, such as would be produced by an igneous rock. He also cited the crumpled strata in the Maritime Alps, in which the granites were parallel with the other beds, and seemed to form part of them.

Mr. CARRUTHERS mentioned that the late Prof. Fleming, twenty years ago, had taught the same doctrine as to the nature of granite as that held by the last speakers. He also stated that similar views would be found expressed in Headrick's 'Mineralogy of Arran.'

Mr. DAVID FORBES agreed that the crumpling of the strata was not due to the intrusion of any eruptive rock. He completely disagreed with Prof. Ramsay and the author as to the origin of granite, and maintained that, in the sedimentary rocks traversed by the granite, the requisite ingredients for the formation of granite did not exist. The proportion of felspar in quartzose rocks was infinitesimally small, as compared with that entering into the composition of granite. He could not accept the notion of the heat from the interior approaching gradually to some portion of the surface.

Prof. RAMSAY, in reply to Mr. Forbes, maintained that some of the slaty rocks of Wales, by extreme metamorphism, would pass into some kinds of granite. As to the conditions of metamorphism of the rocks, this process must have gone on at a time when these older rocks were overlain by a great thickness of more recent beds which have since been removed by denudation.

